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Title:	MODCOPTER: Prompt, Precise Aerial Sample Collection Using Unmanned Systems
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MODCOPTER: Prompt, Precise Aerial Sample Collection Using Unmanned Systems

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Peppy the Pepper Plant (Metzger's Do It Best)

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Introduction: Aerial Systems

- Aerial systems can often do more than ground based systems
  - Better perspective
  - Unaffected by terrain or debris
  - Can complement ground assets/infrastructure

MA State Police


Kevin Grey/U.S. navy

Introduction: UAS Technology

- Today's "enthusiast" level multicopters are cheap (~$1k) and versatile
  - Payloads ~ 1kg
  - GPS navigation
  - Computer stabilized
  - Hackable/extensible
  - Soon to be approved by FAA for commercial use

Introduction: UAS Abilities

- Multicopters(Multi-rotor UAS) such as quadcopters and octocopters offer excellent agility, and of course can hover
- Wide variety of sizes

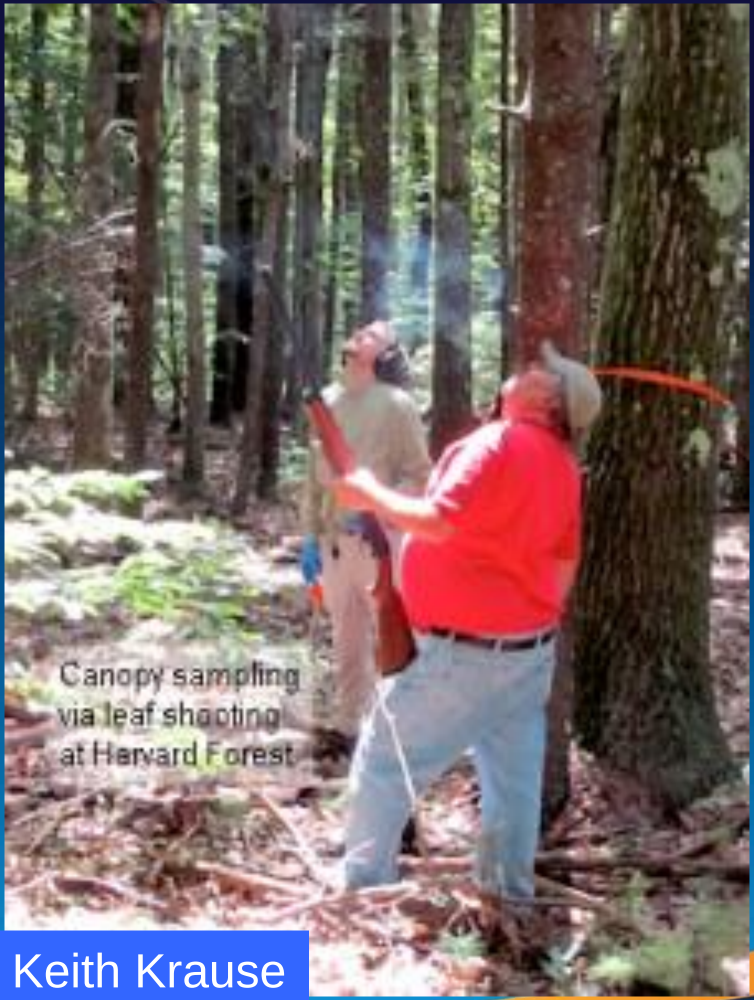
Ars Electronica FutureLab

Sample Collection Needs

- Sample collection is often a manual exercise:
  - Slow, costly, inconsistent and sometimes dangerous
- Leverage technology to produce sample collection that is:
  - Fast, inexpensive, consistent and safe
- Want UAS with ability to interact with environment and thus collect samples
  - Multicopter UAS excellent choice
- This ability would also permit sensor placement
- These would be game-changing technologies for many fields and applications …….
  - National Security (IAEA, etc..)
  - Basic Science (Biology, Geology, etc.)

Use Case: Plant Biology

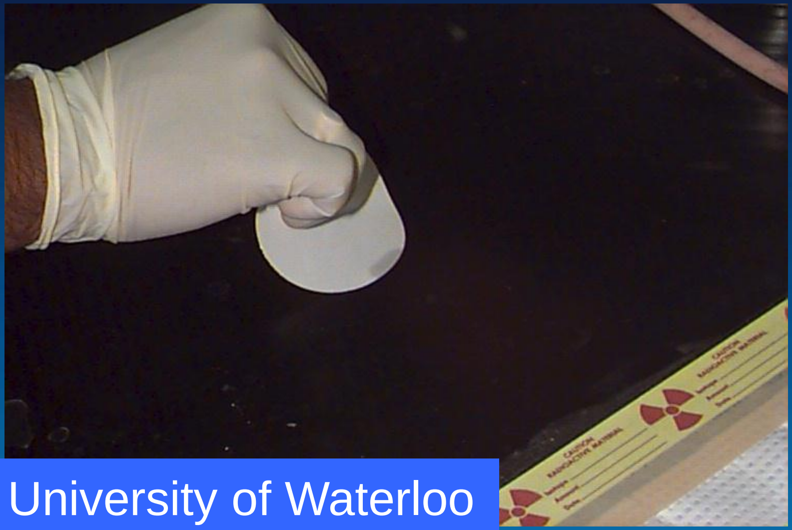
- Want undamaged leaves for study
- Fly UAS to above tree
- ID target leaf
- Fly to leaf
- Grasp/collect leaf
- Place in container
- Return to “base” for leaf analysis



Keith Krause

Use cases: Nuclear Safeguards

- Want to test for surface contamination on top of exhaust vent
- Fly UAS to vent, image and select surface to be tested
- Sample surface with swipe or adhesive pad
- Return to ground with sample for analysis


University of Waterloo

Use Case: Nuclear Forensics

- A nuclear detonation would require samples to ID source and yield
- UAS with manipulator can quickly collect fallout from multiple locations
  - Fly over debris
  - Avoids radiation dose to humans
- Return to base for assay and analysis

http://www.liveworkdream.com/wp-content/gallery/attractions/20080405w_trinitite06.jpg

Use cases: Lava collection

- Want magma present within crater, beyond safe reach
- Fly UAS down into crater, some distance above lava lake
- Lower hook down
- Collect magma
- Return to operator


Jim Cleveland, MyShot

Use Case: Wide Area Sample Collection

- Multiple sample collection from large areas possible
- Drop many collection UAS from larger aerial platform "mothership"
  - Greatly increased range
  - Permits a large number of samples to be collected
  - Also permits a large number of drop sensors to be deployed
- Applications: forest/tundra studies, meteorite hunting, IED detection, etc.

Lockheed Martin

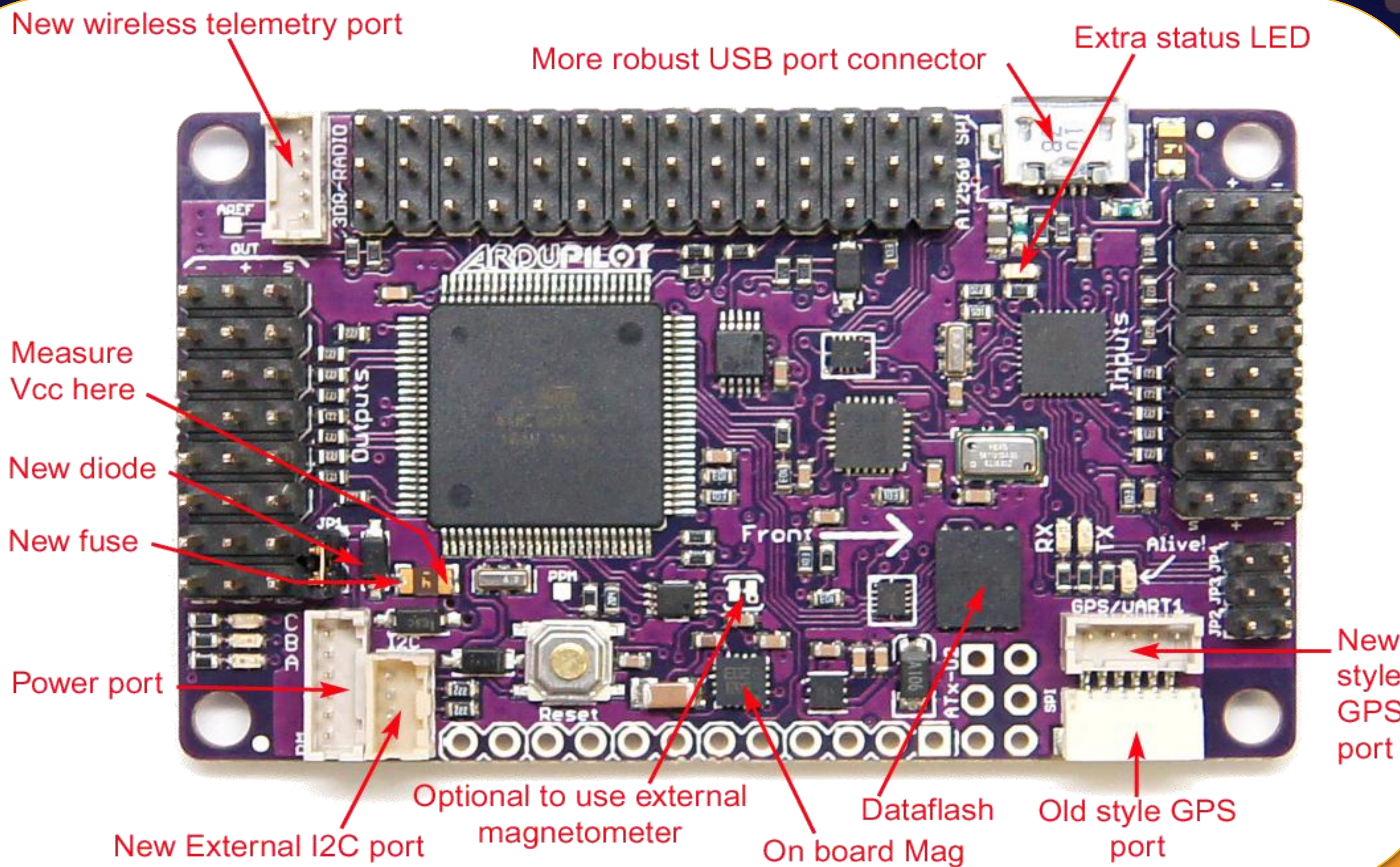
Goals of the MODCOPTER Program

- Manipulation of
- Of
- Diverse
- Compact
- Objects
- for Probes
- of Threats,
- the Environment
- and basic Research

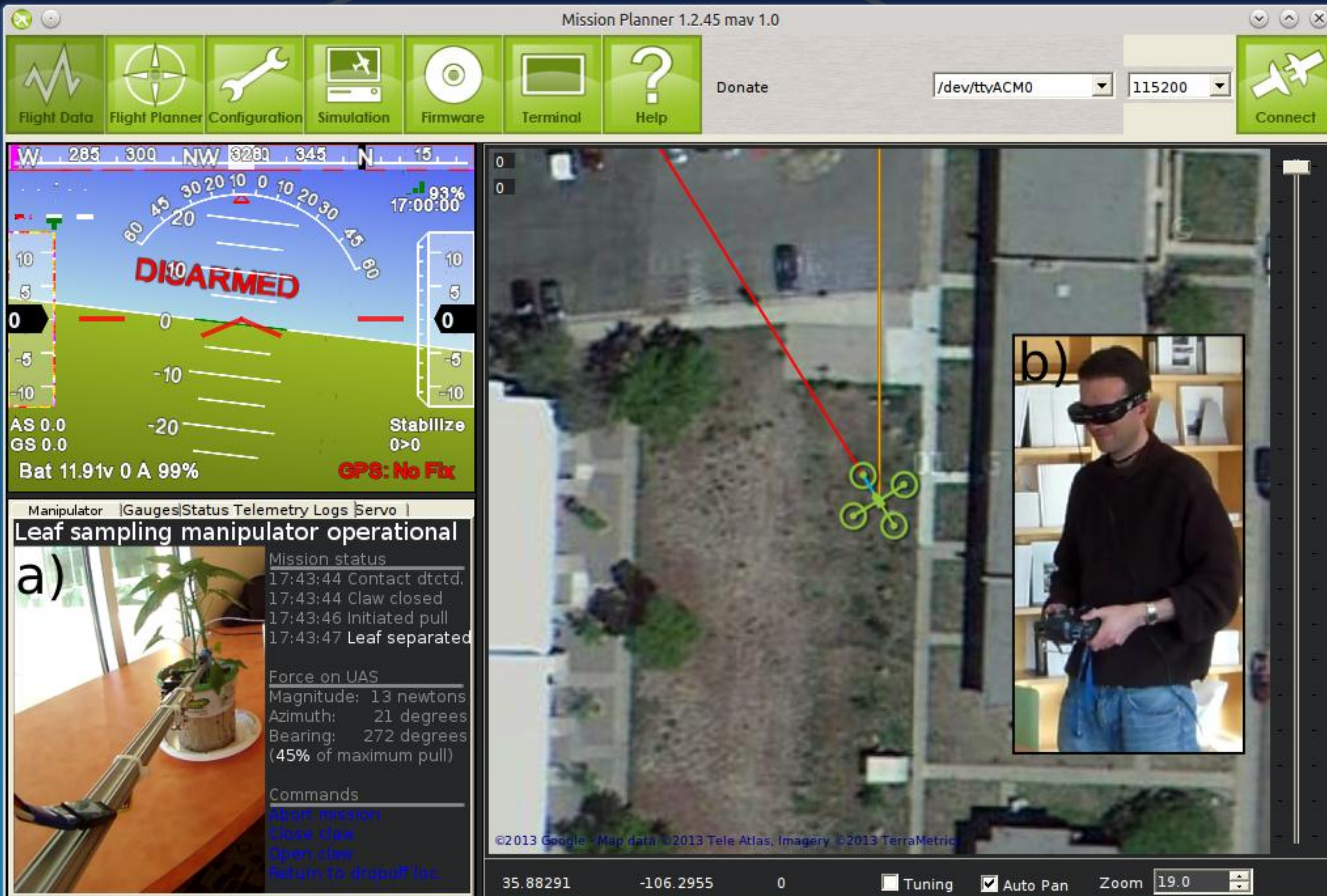
Goals of the MODCOPTER Program

- Evolve UAS as Sample Collection/ Data Collection Platforms
- Develop modular hardware for many UAS to allow interaction with environment
  - Claws, etc.
- Software tools to control the above, and for improved navigation
- User Interface for simple supervised or controlled piloting and/or sample collection

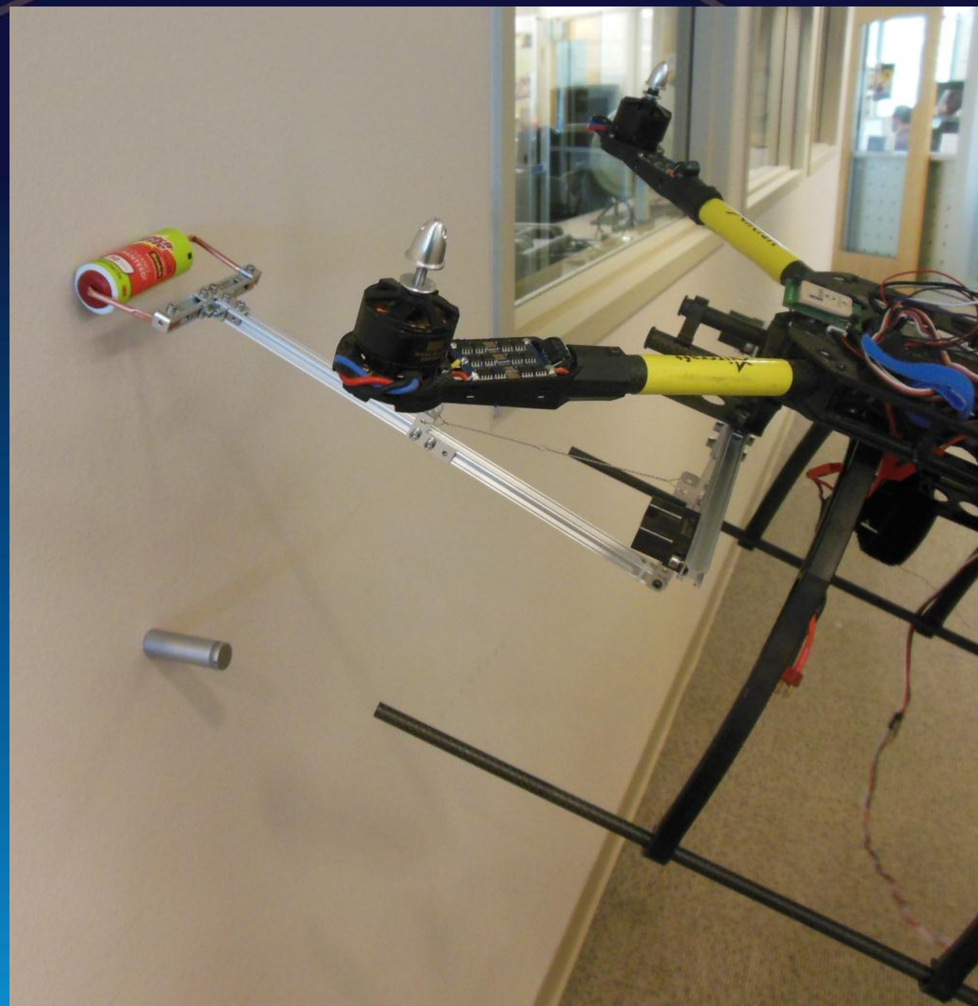
Preliminary Tests: Flight vehicle



Preliminary tests: control system

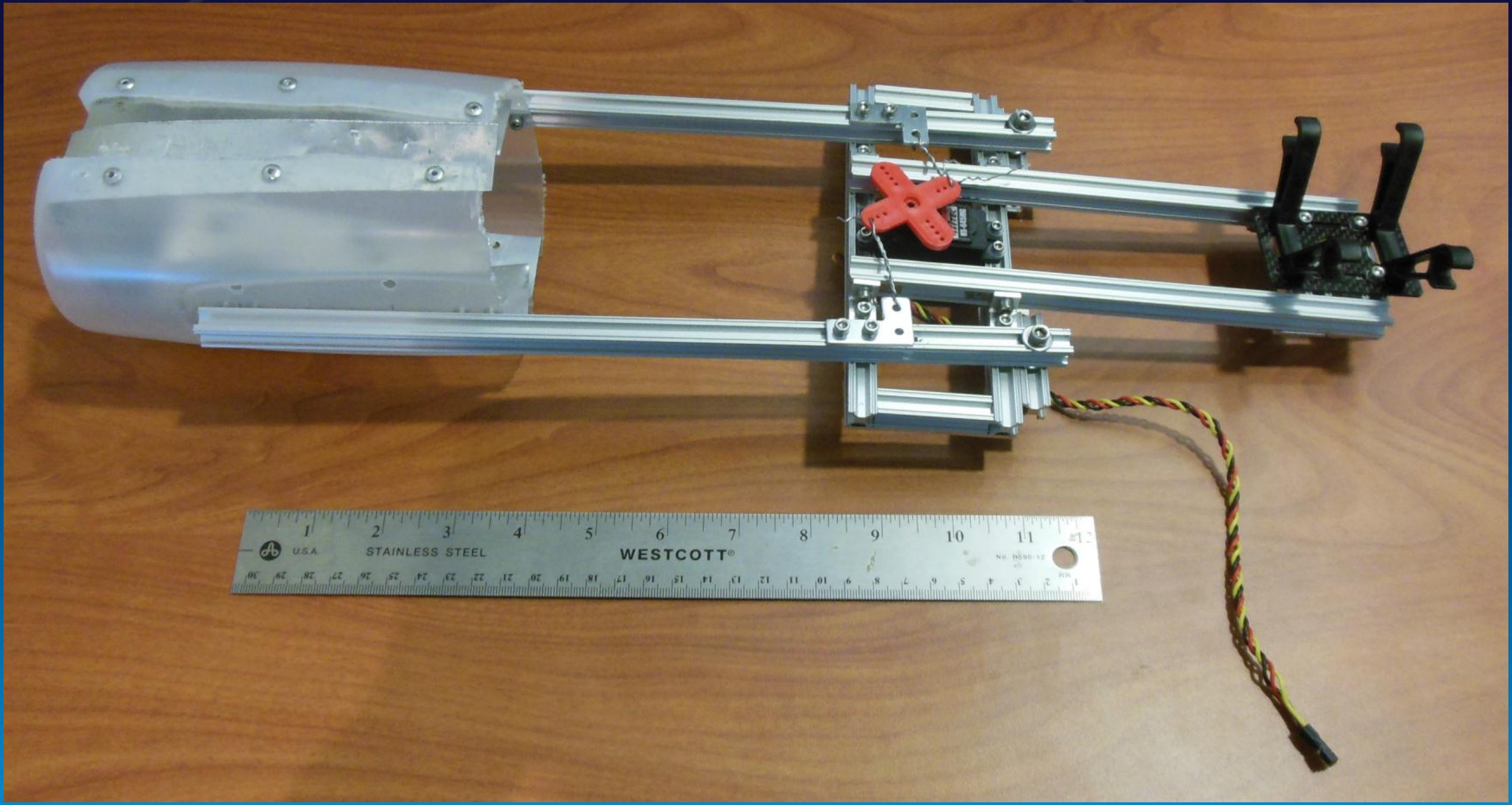


Preliminary tests: contact sampler



Preliminary tests: pinch sampler

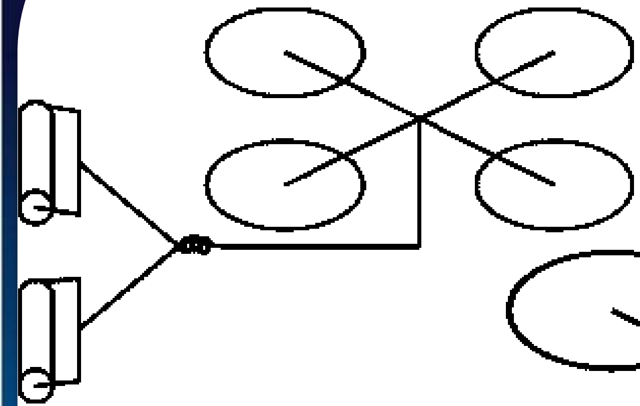
Preliminary tests: grab sampler

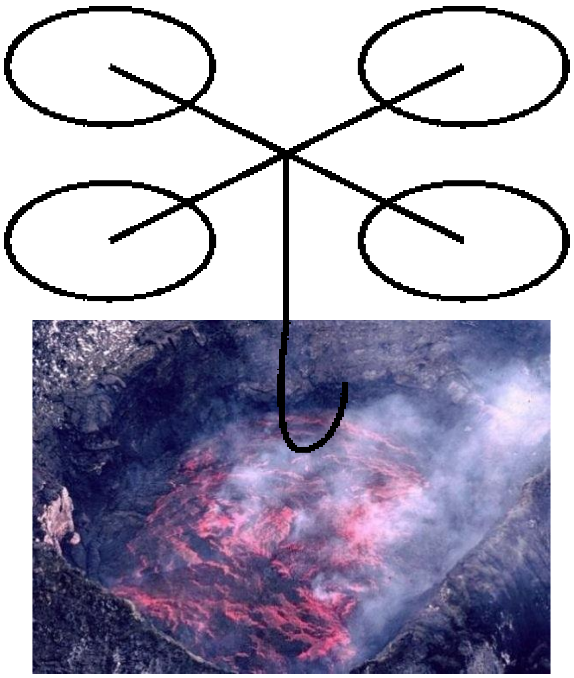


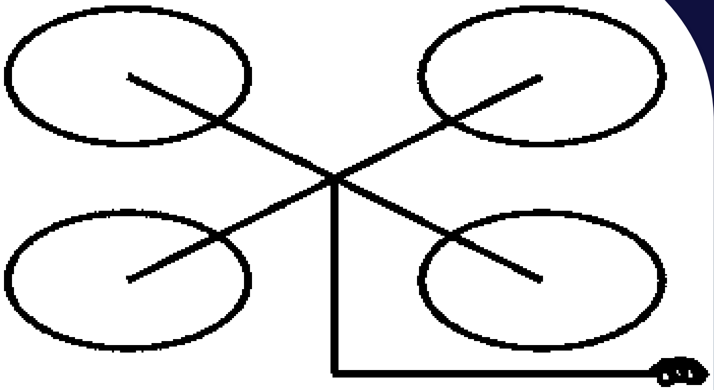
Preliminary tests / lessons learned

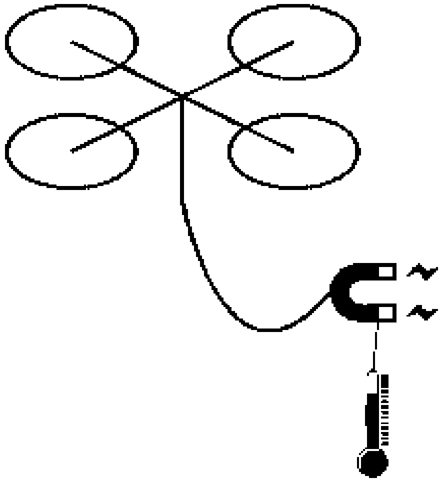
- Pinch sampler
  - Successfully collected plant material
  - Precision maneuvering issue
  - Possible solution: mechanically stabilized arm
- Grab sampler (Mascareñas Mauler)
  - Closed on plant
  - Possible solutions: cutting edge, force feedback
- Contact sampler
  - Successfully collected proxy material
  - Stability issues on rolling attempt
  - Possible solutions: hard limits on pitch angle, multiple rollers

Other manipulators





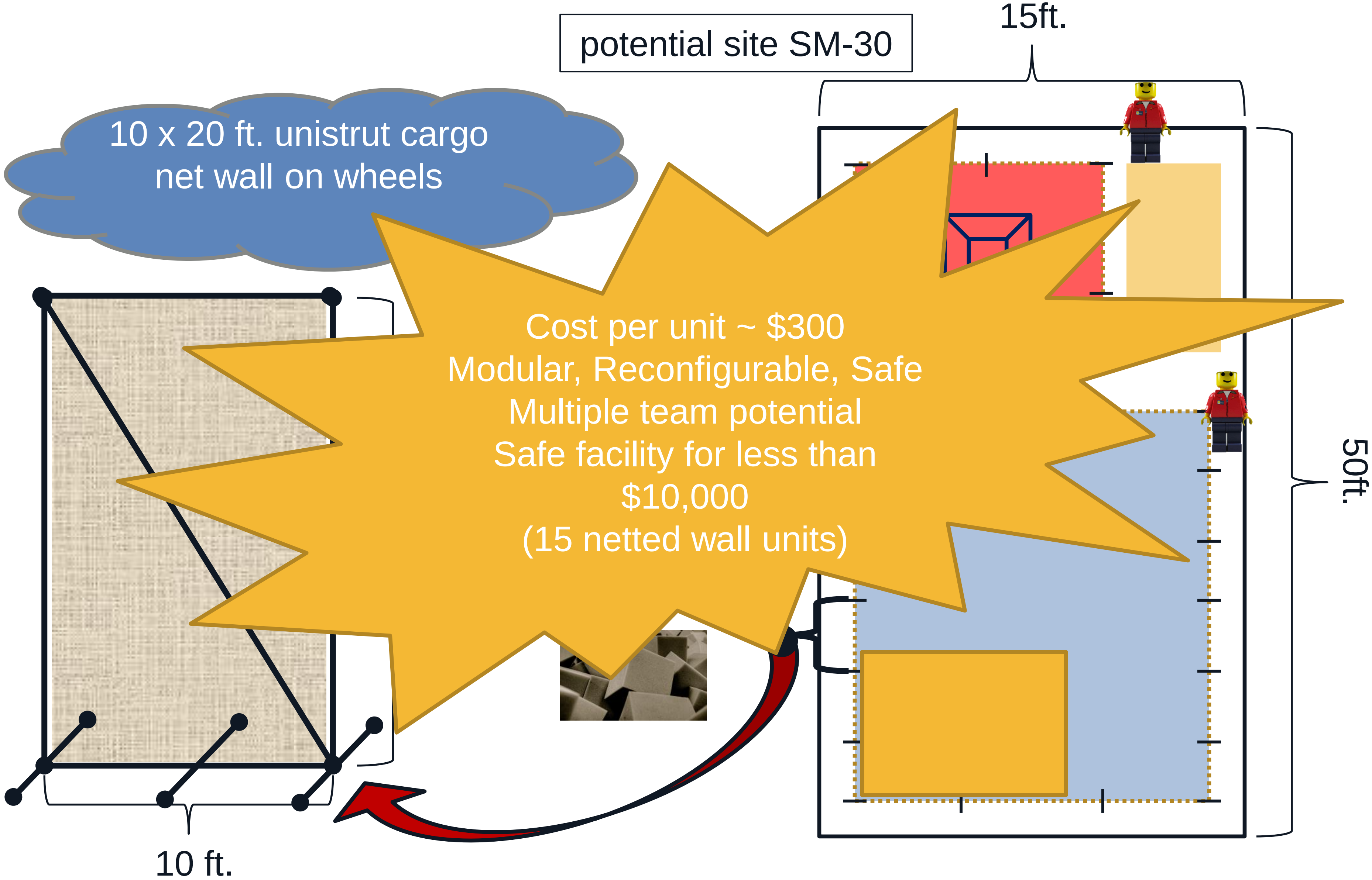




Rapid Innovation Facility

- UAS flight test
  - Safety
  - Camera (AV recording essential)
  - Outdoor conditions vary
- Indoor UAS Testing
  - Develop configurable, safe testing environment
  - Controlled environment
  - Enable secure, compliant recording

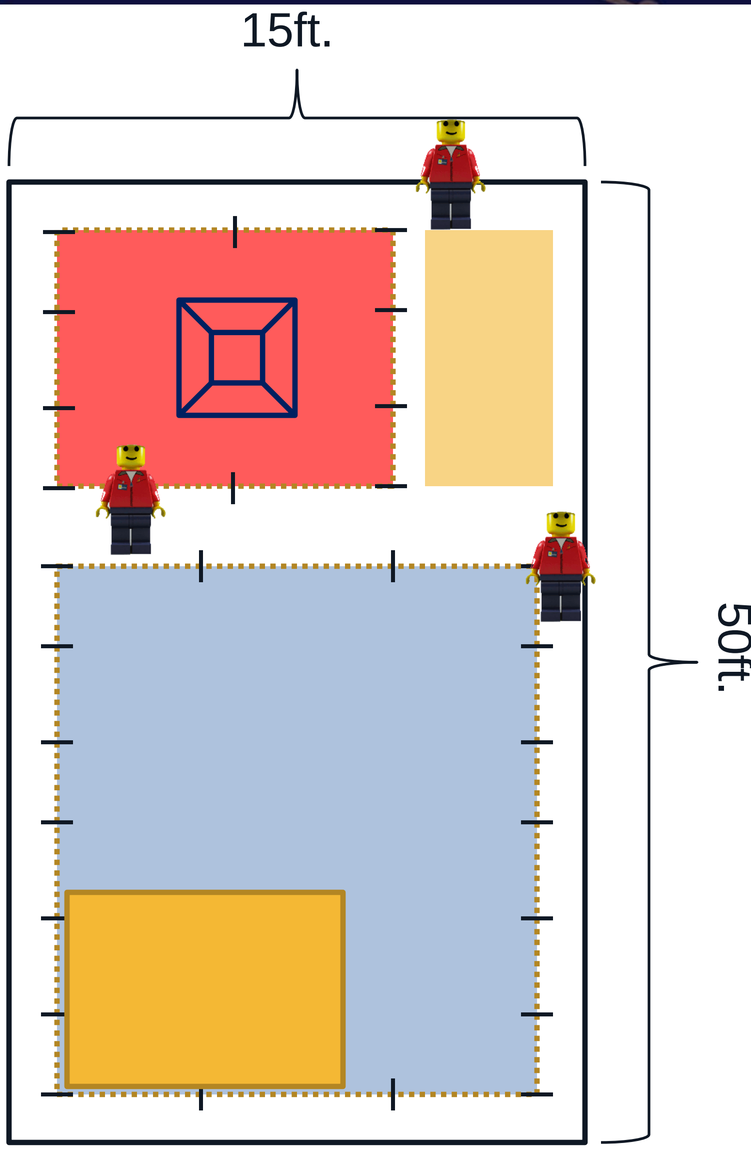
Rapid Innovation Facility



Rapid Innovation Facility

Facility Cost

- Netted units ~ $10,000
- Foam pit ~ $300
- Stability station ~ $1000
- Engineering Station
  - 3D printer station $6000
  - RAX (5 kits) ~ $5,000
  - UAS (10 units)~$10,000
  - Onboard Cameras~$5,000
  - Misc ~ $10,000
  - Vicon System ~ $40,000



Future Work

- Grasping tools
  - Placing items
- Customized autopilot for autonomous tool usage
- Stability
  - Auto-Config of PID parameters based on device
  - Integration of Range Finders with stability algorithms
- Alternative Designs
  - Shock absorbers on roller, multi-roller configuration
  - Cutting capability for Jaw

Task Breakout

Task 1

Safety and Fail-safe

Development of comprehensive safety and fail-safe protocols, procedures, mechanisms, and Integrated Work Documents (IWDs)

Task 2

Mechanical Manipulation Tools

- Development of grasping manipulator
- Development of surface contamination sampling manipulator
- Prototype comparison versus application
- Development of articulated manipulator mounts
- Preserving sample integrity
- Development of Manipulator sensor technology

Task 3

Stability for manipulator equipped UAS platforms

- Performance evaluation of manipulators on different UAS platforms
- Computational requirements for autopilot and on-board stability
- Hybrid mechanical/computational stabilization schemes

Task 4

User control interface and software architecture

- Selectable automatic/manual control of flight
- Selectable automatic/manual control of manipulator system
- Manipulator control interface and monitoring system
- Integration of flight telemetry and on-board sensors into data and documentation stream
- Computer vision for supervised target approach and selection

Task 5

Testing and refinement

- Safety and Fail-safe compliance
- Testing of sample collection
- Benchmarking of sample integrity mechanisms
- Evaluation of compliance to IAEA standards for relevant sample collections methods

Budget

Title	Role	FTE	FY14 Cost	FY14 Effective Estimated Cost
Principal Investigator (R&D 2)	Overall scientific management	0.5	305,536.28	152,768.14
Project Management (R&D 2)	Overall project oversight	0.25	305,536.28	76,384.07
Mechanical Engineering Lead (Postdoc)	Oversight of mechanical systems	1.0	162,256.71	162,256.71
Software Engineering Lead (Postdoc)	Oversight of software and user interface	1.0	162,256.71	162,256.71
Machine Vision Lead (Postdoc)	Oversight of targeting and navigation systems	1.0	162,256.71	162,256.71
Testing Coordinator (Postdoc)	Oversight of Testing Procedures and Data Analysis	1.0	162,256.71	162,256.71
Graduate Researchers	Construction and Programming Project-wide	4.0	111,327.15	445,308.60
Materials, Supplies and Travel	Facility, Supplies, Travel		170,000.00	170,000.00
TOTAL				1,493,487.64

Broader Impact

- Fundamental Research focused on UAS
  - Control Theory for Aerial Systems for physical interaction
  - Novel algorithms and programming paradigm
  - Human UAS interaction
- Safe, Leadership-class UAS research at LANL
  - Reality within 1st year of funding
  - Capability for corporate and intra-LANL partnerships
  - Strategic position as premier UAS research center
- Research that can impact the world
  - Agriculture, Volcanologist, …

Acknowledgements

- Jutta for watching Peppy, and handling the logistics of the Advanced Scholars Program
- Chuck and David for organizing the Advanced Scholars Program
- Prof. Philip Kyle (NM Tech)
- Prof. Frank Mueller (NC State)
- P-23 Weak Interactions Team + MiniCLEAN collaboration
- The proposal reviewers
- All speakers for their time and efforts
- Dr. Jennifer Wright for ecological perspective

Extra Slides